# Classification of nodes transforming topological model of biological process to a dynamic functional model

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## Abstract

*Homomorph transformation of topological model into a functional model of a biological system is discussed from the point of view of node classification by their features.*

*Topological model of bee colony microclimate control in winter is analysed as an example. Model contains 28 nodes and several control loops.*

*Following types of nodes in the topological model of microclimate control in wintering bee colony were determined: 1) constant nodes, 2) numerically calculated nodes, 3) integrative (inertial) nodes, 4) environmental impact nodes, 5) decision nodes, 6) decision guided execution nodes.*

*Decision nodes are analysed more detailed in case of possible activation of several control loops in parallel and in different proportions.*

***Keywords:*** *microclimate control, topology, honeybee, wintering.*

## Introduction

Modelling of complex biological processes require several modelling levels depending on the modelling task. Developing dynamic model of a system usually topological model (Ore, 1962; Osis, 1969, 1970) is used to demonstrate cause-effect relationships. Nodes of topological model represent parameters and arrows represent the art of relationship. Next step is homomorph transformation of topological model into functional model with numerical relationships between nodes where dynamics of a system can be simulated (Stalidzans, 2005).

Topological model of biological control system represents different control loops (Weyrick, 1975; Dorf and Bishop, 2005). Control loops can work simultaneously or exclusively (one loop can be activated only if the other one is passive). Thus the way of decision making of biological system has to be represented transforming topological model to functional model. This is a complicated task compared to technical systems as decision can be estimated only from experimental results assuming that all control loops of biological object are represented in the model.

Topological modelling was used developing dynamic model of microclimate control in wintering honeybee colony (Stalidzans, 2005).

During model transformation into the functional one turned out that there are different arts of nodes and their classification can improve transformation process.

The goal of this paper is to analyse different groups of topological model parameters by the way of their transformation into a functional model to simulate dynamics of a system.

## Methods of investigation

Topological model of microclimate control of bee colony in winter is analysed. Industrial honeybee colonies are usually wintered in hives. When in cold season outside temperature decrease to +8$^{o}$C bees start to form cluster – mechanism for collective microclimate control at low temperature (Furgala and McCutchenon, 1992).

Four microclimate parameters in the bee cluster are analysed: water content in the air ($H_2O$), carbon dioxide concentration in the air ($CO_2$), oxygen concentration in the air ($O_2$) and temperature of the air. Choice of named parameters is determined by metabolic reaction where honey and oxygen are build carbon dioxide, water and warm. Honey is not taken into account as microclimate parameter as it is not present in air.

In microclimate control process are three environments involved with different microclimate parameters (Figure 1): 1) bee cluster, 2) hive (space in hive that is not occupied by bee cluster) and 3) outside air. Microclimate control process is typical homeostatic enthropic process where bees in the cluster try to create and maintain different environment compared to the outside air. Different processes like air exchange, diffusion, radiation, heat conduction and others act to equalise cluster air with outside air. Bees in the cluster act to compensate those processes (control of metabolism by muscle activity, control of air exchange by cluster density) the above mentioned processes and keep microclimate parameters optimal for particular circumstances.

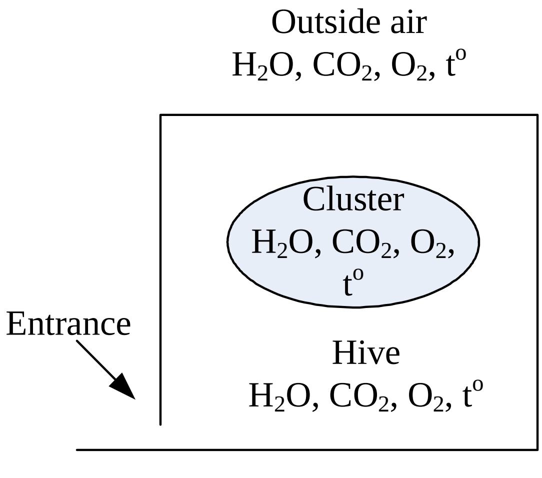


*Figure 1. Three environments in control process of microclimate: cluster, hive and outside air.*

Earlier developed topological model (Figure 2) of microclimate control of bee colony in winter (Stalidzans, 2005) is analysed to split the nodes and relationships in different groups by art of their calculation or description.

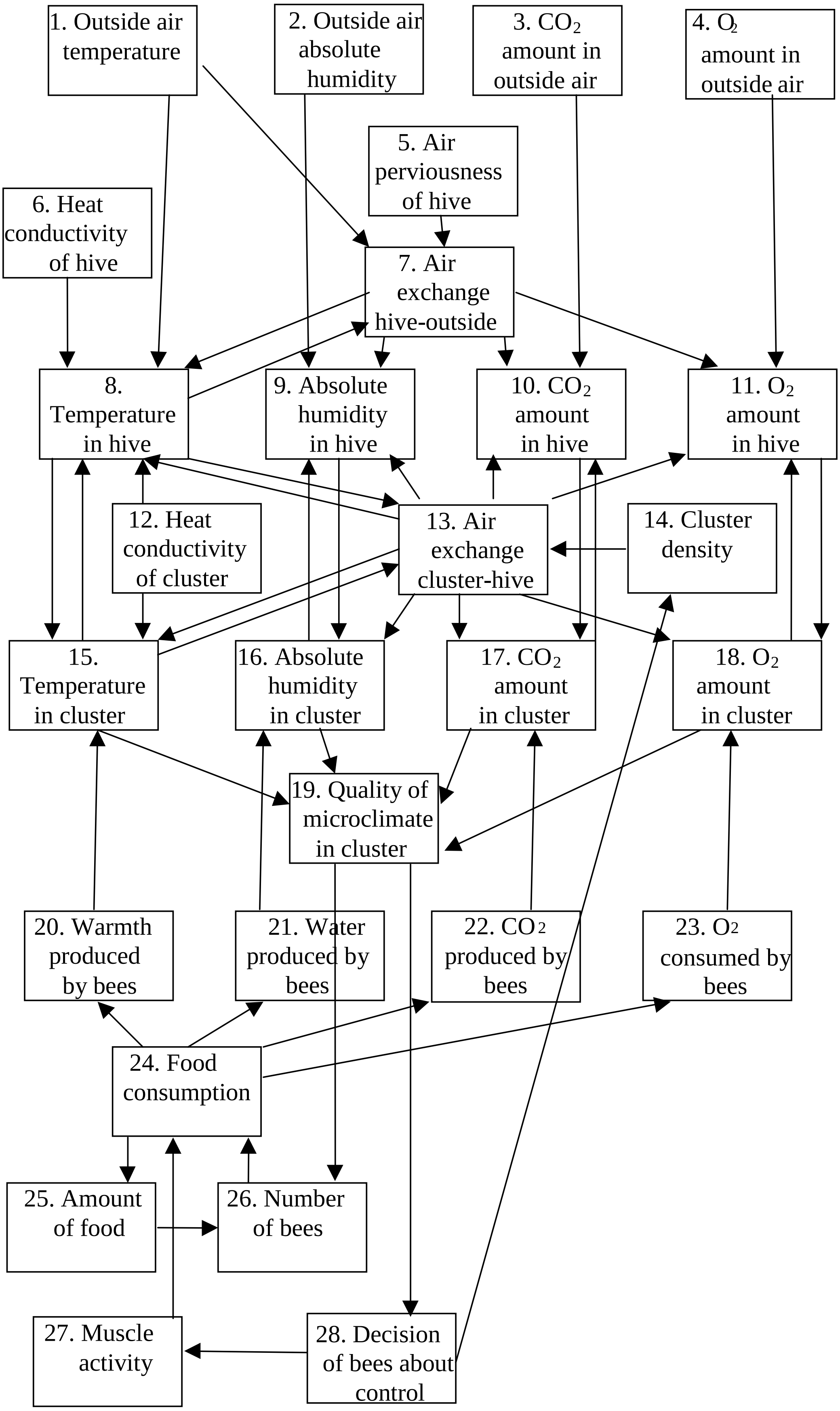


*Figure 2. Topological model of microclimate control of bee colony in winter.*

## Results

Different groups of nodes are determined analysing process of homomorph transformation of topological model into functional model where dynamic simulation has to be performed.

Nodes in the topological model can be classified as follows:

Constant nodes (No. 3,4,5,6 in the Figure 2).

Constant nodes have constant value and have no influence from other nodes in the model. Usually they are transformed as single nodes.

Numerically calculated nodes (No. 7, 12,13,24).

This kind of nodes are subject of mathematical calculation from values of their input nodes. Transforming this kind of nodes from topological model they can develop to a group of nodes because of various reasons: to see intermediate results or test calculations.

1. Integrative (inertial) nodes (No. 8,9,10,11,15, 16, 17, 18, 20, 21, 22, 23, 25).

New value of these parameters depends on their earlier value. For instance, concentration of gas in next time step of simulation is a function of earlier value and changes within simulation time step. This kind of nodes in a functional model requires a kind of memory to keep the value of previous step. Starting simulation integrative nodes need their initial value.

Integrative node can be transformed into functional model as a group of nodes or single node depending on initial value definition.

2. Environmental impact nodes (No. 1 and 2).

This kind of nodes are variables and have no influence from other nodes in the model. They represent environmental impact on the simulated system. Environmental impact nodes usually are linked to a database or real-time experimental data source. Their representation in different simulation software is specific.

3. Decision nodes (No. 19 and 28).

Decision nodes are specific for biological objects as they characterise dynamic parameters of control loops and their interaction. In a functional model they can be represented as "if-then" type of rules, as cluster of nodes using expressions of vectorial optimisation. Hierarchy of decisions in case of several alternative or exclusive control loops has to be defined by interlinking them in the functional model.

Usually the data in decision nodes are not numerical. That cause additional difficulties interpreting them in functional model.

In case of wintering bee colony topological model (Figure 2) decision node "19 Quality of microclimate in cluster" has to give a signal to another decision node "28 Decision of bees about control" for execution of two possible control mechanisms that are independent and can be executed simultaneously if quality of microclimate is low. Complexity of this cascade in functional model is determined by necessity from the value of node 19 decide in node 28 which of two possible control mechanisms has to be activated. Should they act in parallel? In which proportion they should be used?

In case of tuning dynamic model to experimental data the way of decision representation can become critical. If decision rules in the model are represented wrong way computational optimisation may not find right coefficients even if rest of the model represent the system well.

This kind of problematic is specific for biological systems where our task is to find out the rules of existing control system instead of development of new one.

4. Decision guided execution nodes (No. 14, 26, 27,28).

Execution of decision contains parameters of control loops determining their dynamic properties. If a control loop is activated by decision node, appropriate decision guided execution node becomes activated. Information from decision node can come in different form: numerical, textual and so on. Decision guided execution nodes usually have to be calibrated and adjusted to correspond to experimental data. In a functional model this kind of nodes can be represented as a group of nodes.

Classification of nodes gives opportunity to determine nodes with different functions and standardise their representation transforming topological model into functional model of a biological system.

## Conclusions

Topological model of biological control systems contains different arts of nodes causing different way of their describing in case of dynamic modelling of biological control system.

Following types of nodes in the topological model of microclimate control in wintering bee colony were determined:

1) constant nodes,
2) numerically calculated nodes,
3) integrative (inertial) nodes,
4) environmental impact nodes,
5) decision nodes,
6) decision guided execution nodes.

Features that have to be taken into account developing functional model from a topological one classify above-mentioned types. Classification of nodes has to done by domain experts of modelled object.

The most specific nodes for biological systems are decision nodes that are not typical modelling technical systems. Wrong interpretation of decision node may lead to wrong dynamic model in case of several competing control loops.

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